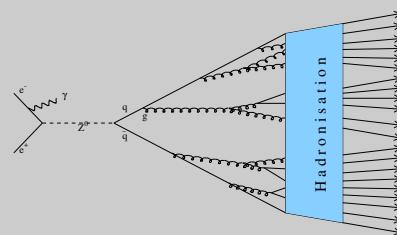


# Inclusive Analysis of

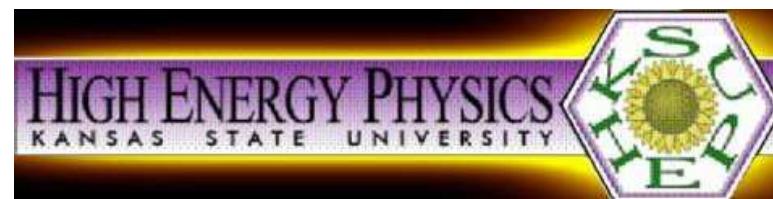


## b Hadronization

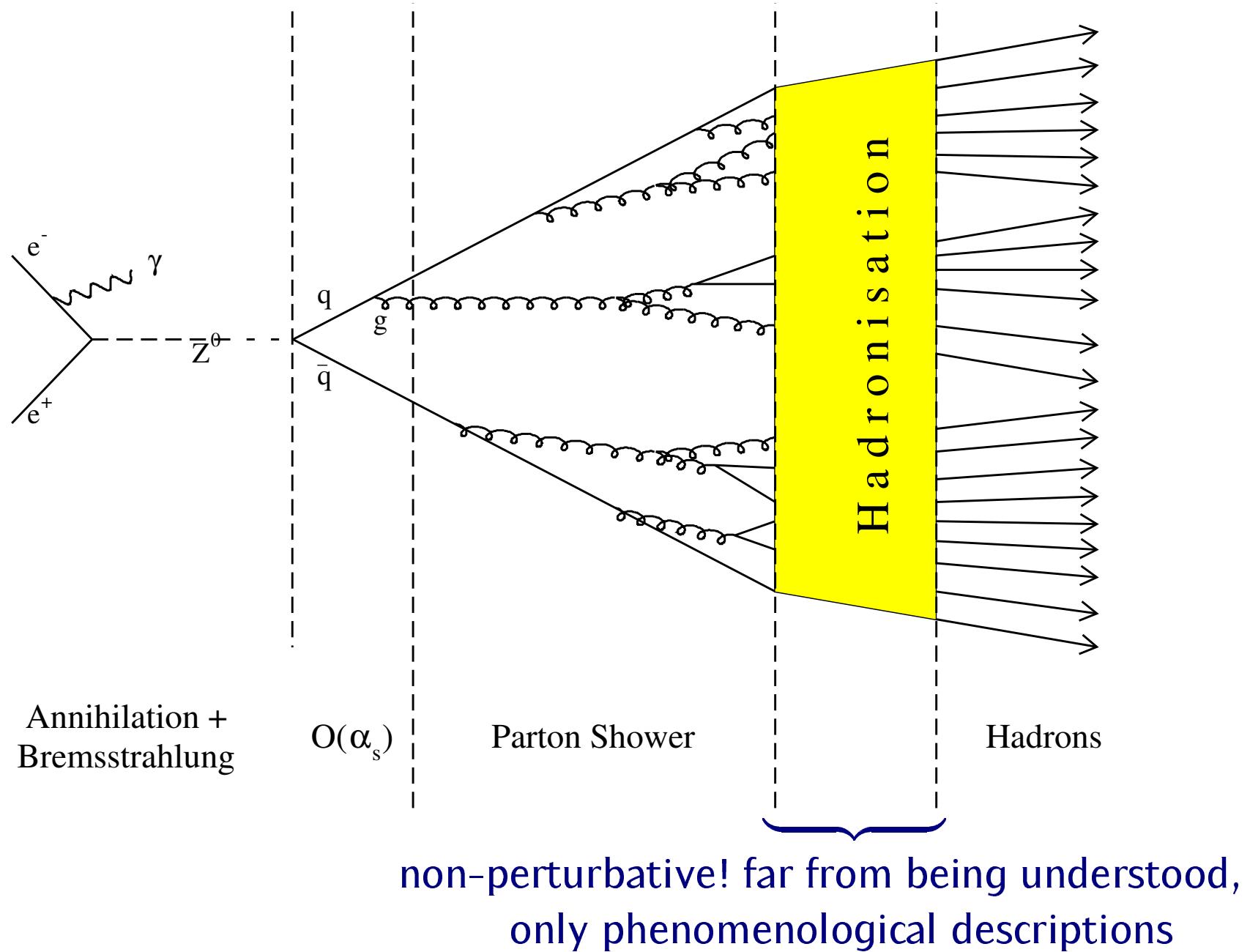
### in Z Decays at OPAL



This talk sponsored by



# Production of b hadrons in Z-decays



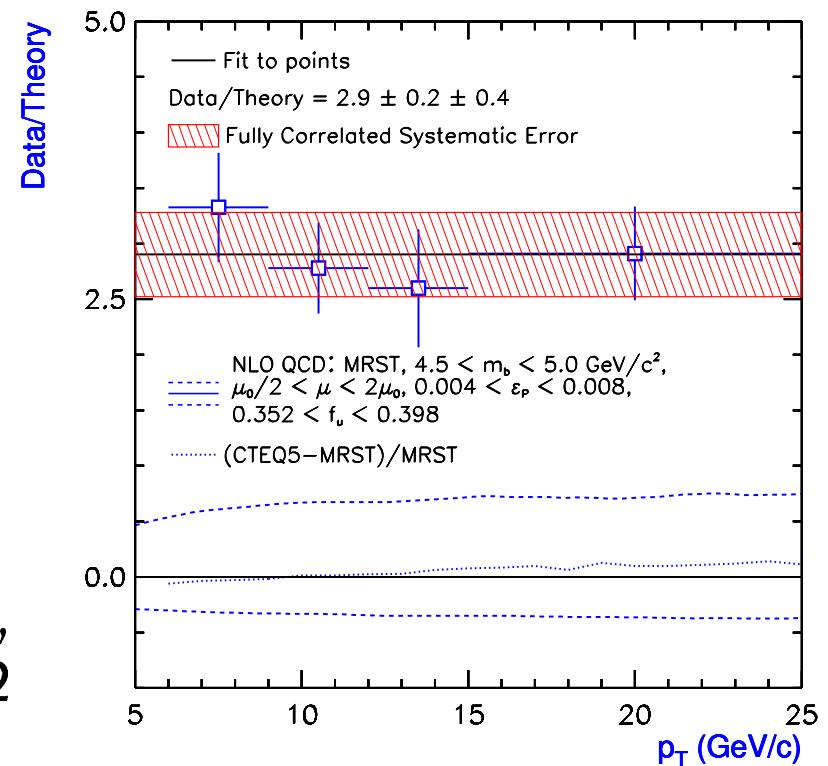
picture by A. Leins

# WHY should we investigate b hadronization?

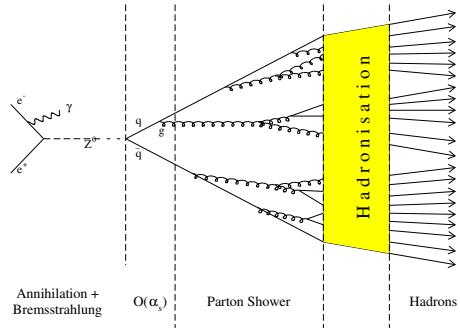
- new insights into non-perturbative QCD?
- reduction of important systematic uncertainties

**Example:**  
CDF  $B^+$  cross-section measurements  
possibly affected by  
hadronization mismodeling!

CDF Collaboration,  
Phys. Rev. D65:052005, 2002



# HOW should we investigate b hadronization?



No experimental separation between perturbative and non-perturbative part  
→ have to measure both together

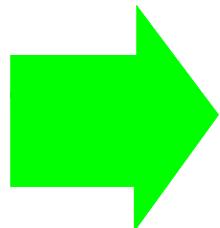
- ★ Measure energy distribution of weakly decaying B hadrons!
- ★ Compare to Monte Carlo simulation using specific hadronization model, fit parameters to optimize agreement
- ★ Give model-independent description of B hadron energy spectrum

# Selection and reconstruction of B hadrons

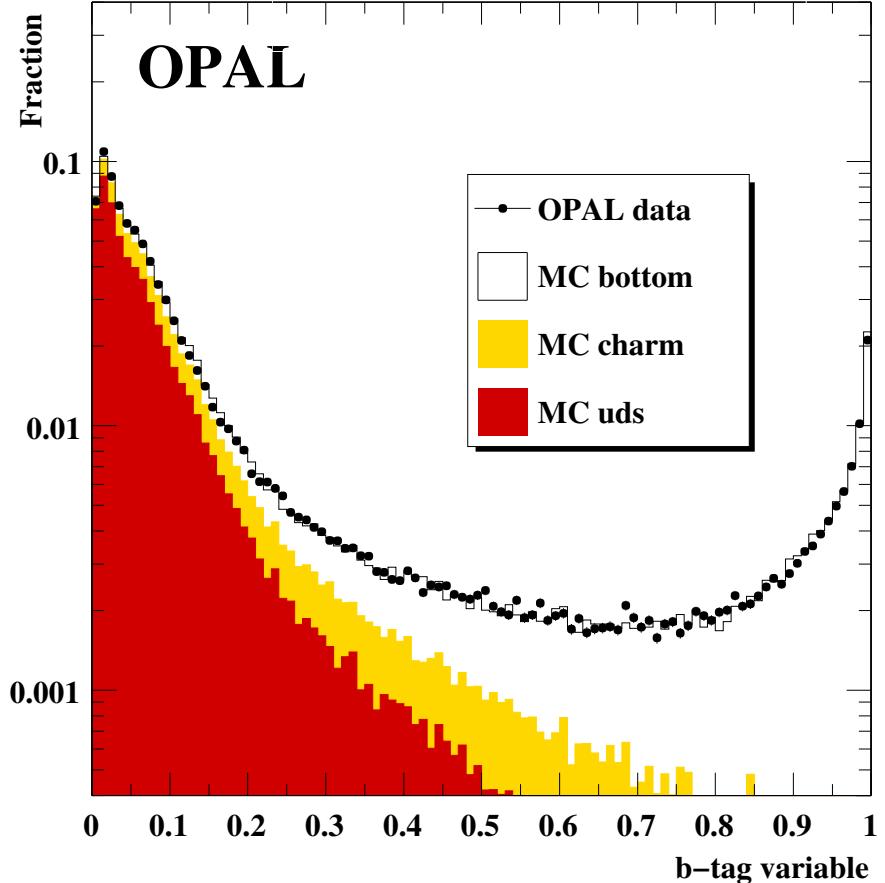
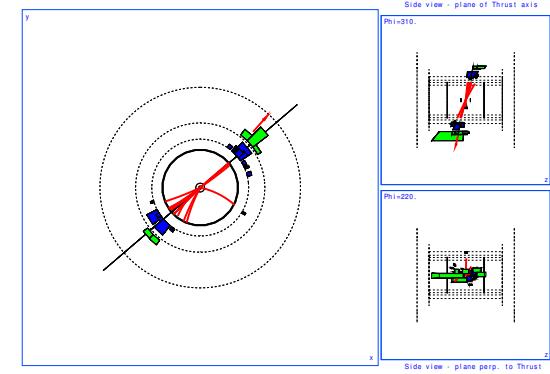
Run:event 2776: Ctrk(N= 17 Bump= 47.8) Elec(N= 40 SumE= 41.7)  
Ebeam 46.60 Vtx (-0.02, 0.05,-0.05) Had(N=14 Bsum= 21.0) Muon(N= 1)



- selection of b jets  
(OPAL Higgs b tagger)
- reconstruction of B decay vertex
- selection of B hadron decay products  
artificial neural nets identify tracks and clusters from B decays
- estimation of the B hadron energy  
(see next slide)



reconstruction efficiency: 16%  
background contamination: 4%  
energy resolution  $\approx 10\%$



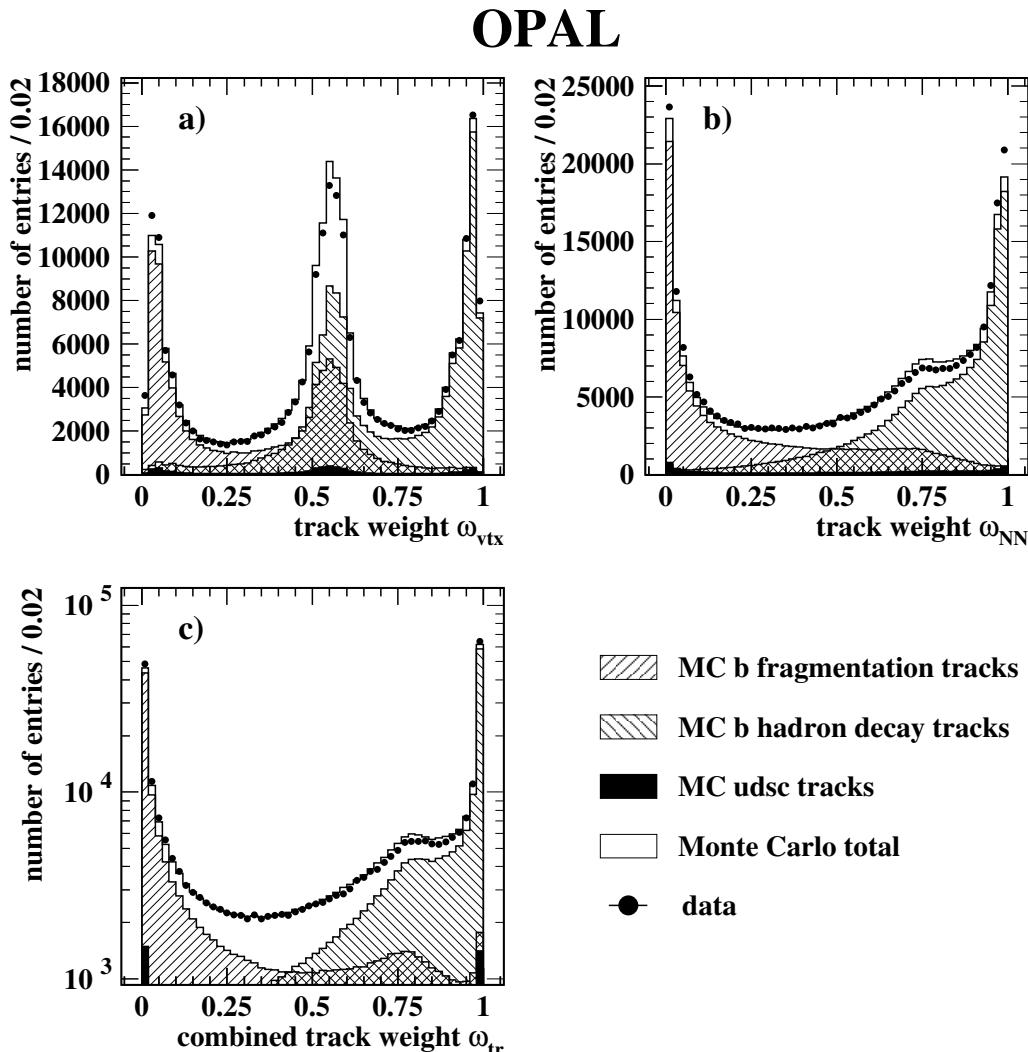
# B hadron energy estimation

ideal case:  
add energies of  
B decay products

problem:  
which tracks/cluster are  
B decay products?

solution:  
add energies of  
*all* tracks/clusters,  
weighted by  
neural net B probability

≈10% energy resolution



# fragmentation functions (should be: “hadronization functions”)

Peterson et al.

$$f(z) \propto \frac{1}{z(1 - \frac{1}{z} - \frac{\epsilon}{1-z})^2}$$

→ estimation of transition matrix element by energy difference

Collins/Spiller

$$f(z) \propto (\frac{1-z}{z} + \frac{(2-z)\epsilon}{1-z})(1+z^2)(1 - \frac{1}{z} - \frac{\epsilon}{1-z})^{-2}$$

→ from correspondence to heavy meson structure functions

Kartvelishvili et al.

$$f(z) \propto z^\alpha (1-z)$$

→ from correspondence to different model of heavy meson structure functions

Lund symmetric

$$f(z) \propto \frac{1}{z}(1-z)^a \exp(-\frac{bm_t^2}{z})$$

→ symmetry wrt. start of string hadronization at either end of the string

Bowler

$$f(z) \propto \frac{1}{z^{1+bm_t^2}}(1-z)^a \exp(-\frac{bm_t^2}{z})$$

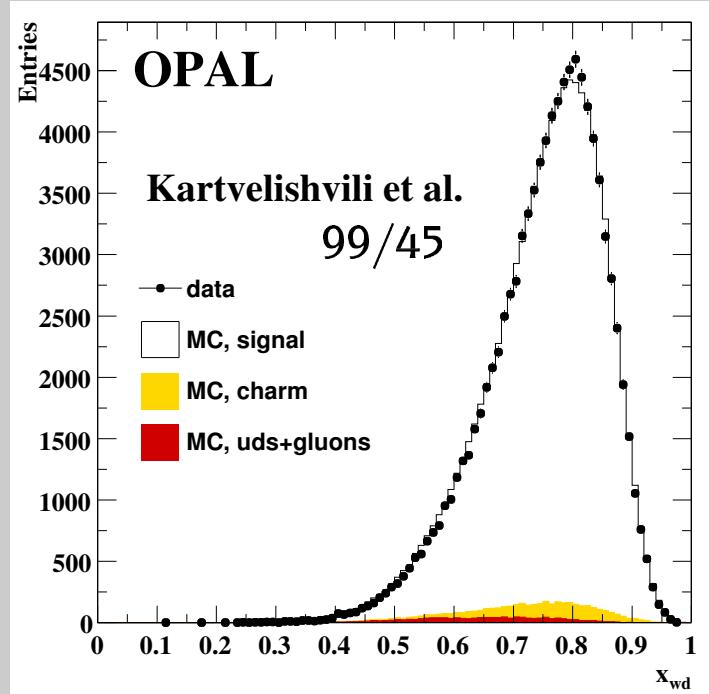
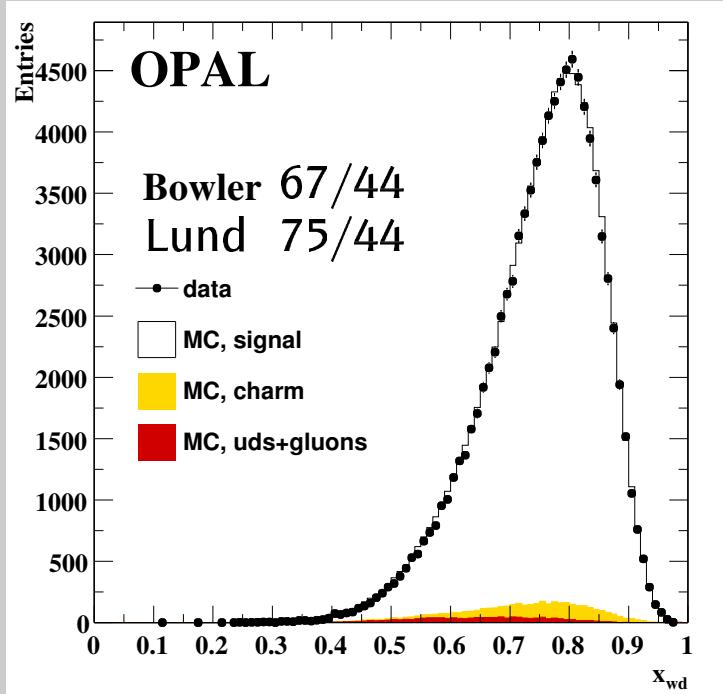
→ constant probability per length and time for  $q\bar{q}$  creation on the string

# Comparison of the energy distribution with model predictions

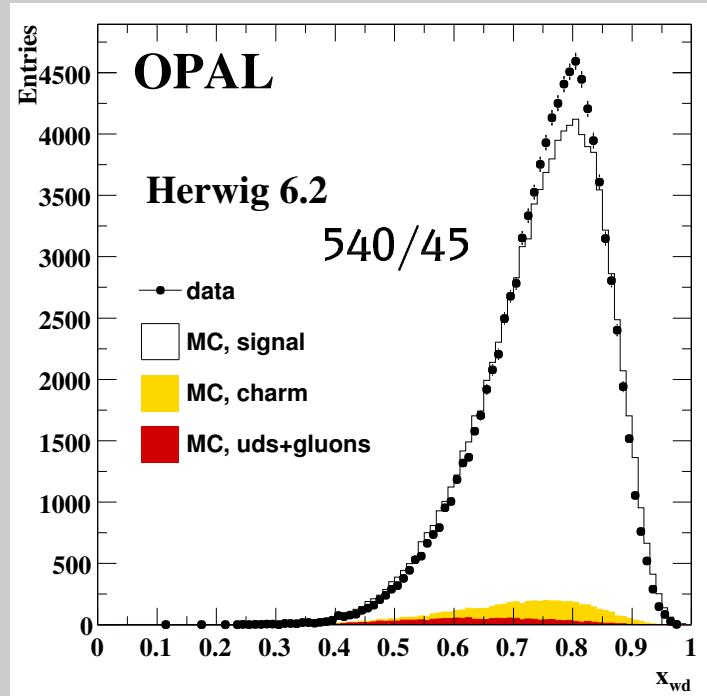
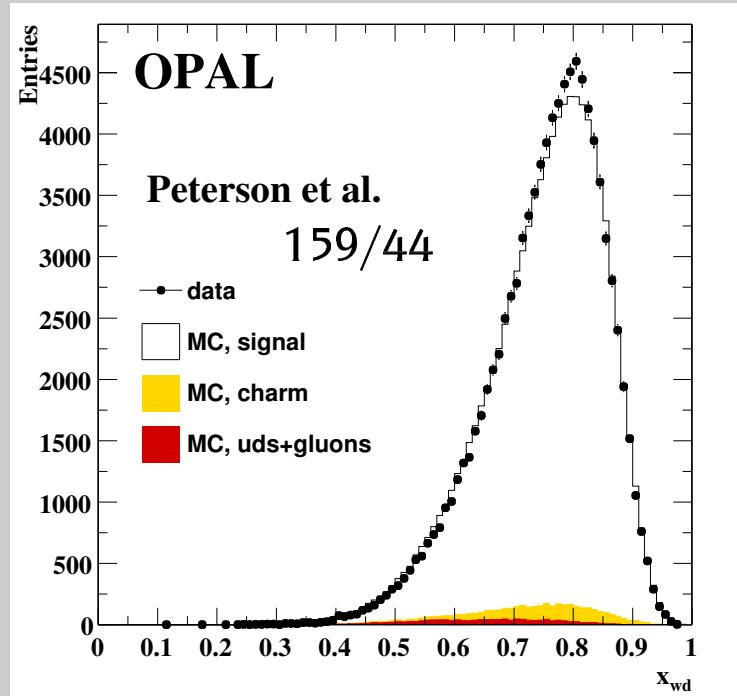
Plug hadronization model into Monte Carlo sample,  
fit parameters to data using the B hadron energy distribution

plots show scaled energy  $x_E = \text{B hadron energy} / \text{beam energy}$

best agreement with data ( $\chi^2/\text{degree of freedom}$ , only statistical uncertainty):



some worse examples:



Clear distinction between models!  
Same ranking seen in recent ALEPH, SLD, DELPHI analyses

→ important input for QCD phenomenology

# model-independent description of the B hadron energy spectrum

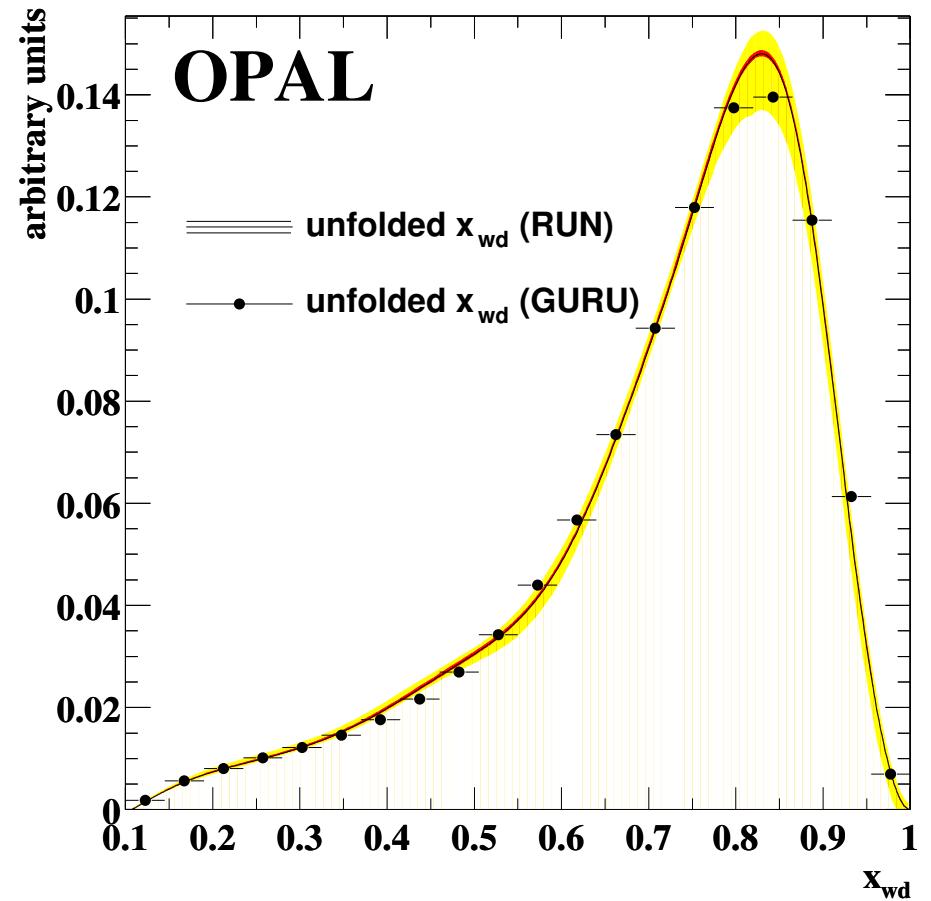
have to use **unfolding** to correct for

- energy dependent efficiency
  - finite detector resolution
  - energy dependent reconstruction bias
- two methods used: RUN, SVD-GURU

mean scaled energy of  
weakly decaying B hadrons:

$$\langle x_E \rangle = 0.7193 \pm 0.0016^{+0.0038}_{-0.0033}$$

dominant systematic uncertainty:  
detector resolution modeling

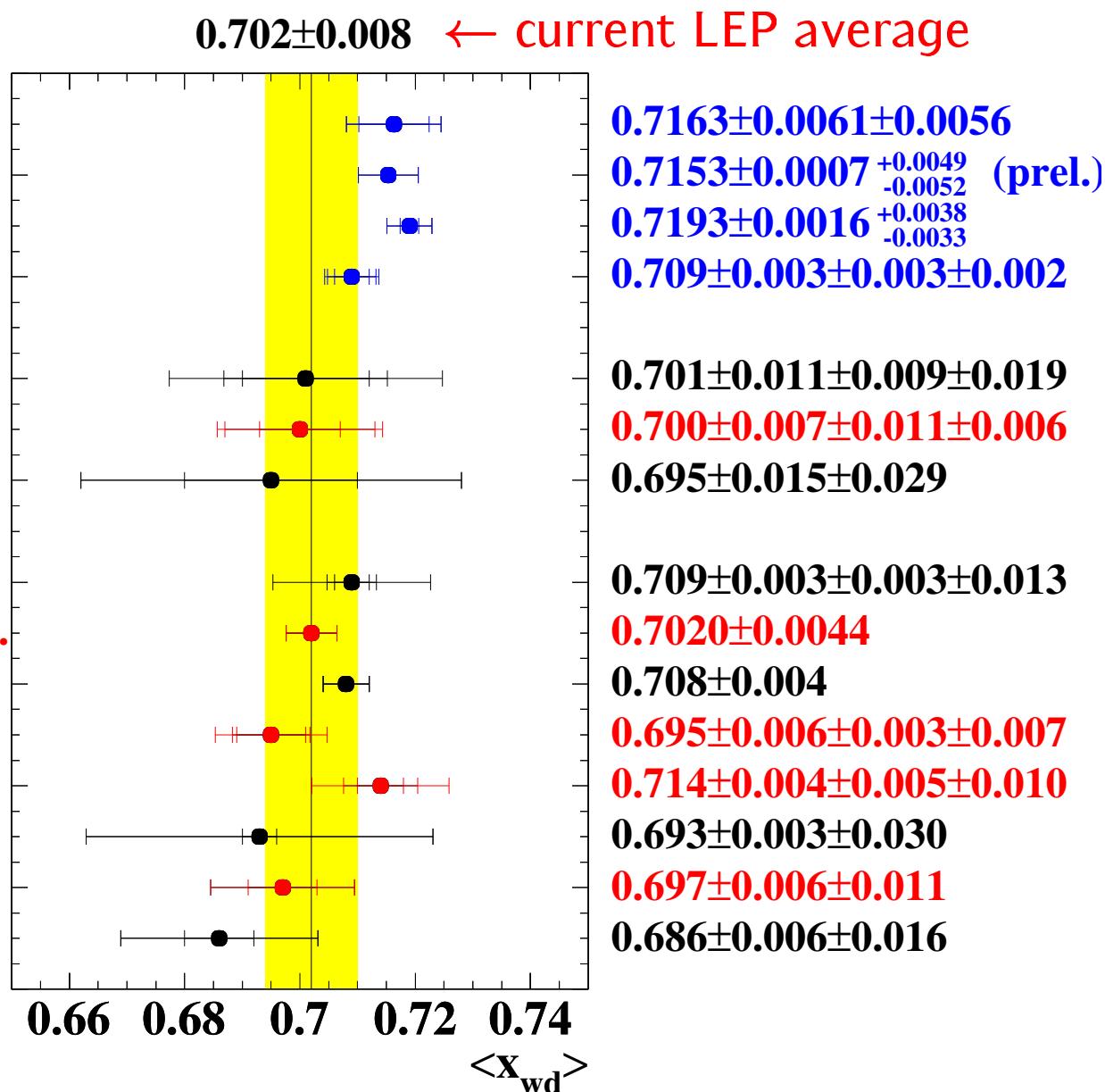


# Overview of $\langle x_E \rangle$ measurements

ALEPH (01)  $B \rightarrow D^{(\bullet)} l \nu$   
 DELPHI (02) inclusive  
 OPAL (02) inclusive  
 SLD (02) inclusive

SLD (96)  $B \rightarrow D^{(\bullet)} l \nu$   
 ALEPH (95)  $B \rightarrow D^{(\bullet)} l \nu$   
 DELPHI (93)  $B \rightarrow D^{(\bullet)} l \nu$

OPAL (99) Lepton Spec.  
 DELPHI (95) Lepton Spec.  
 L3 (95) B Lifetimes  
 OPAL (95)  $E_{ch}, M_{ch}$   
 ALEPH (94) Lepton Spec.  
 OPAL (94) Charge Mult.  
 OPAL (93) Lepton Spec.  
 L3 (91) Lepton Spec.



Plot by P. Bechtle

# CONCLUSIONS

- ★ new b hadronization measurement by OPAL “almost” published  
(hep-ex/0210031; EPJ referee’s comments answered last week)  
compatible with new ALEPH, DELPHI, SLD results  
compatible with old results; errors at least factor 2 smaller
- ★ clear hierarchy of hadronization models established  
Bowler, Lund clearly favored; Peterson et al., Herwig worse
- ★ model-independent description of B hadron energy spectrum  
e.g. to improve hadronisation modeling for the Tevatron:

Cacciari/Nason,  
hep-ph/0204025:  
moment space fit  
→  $B^+$  Data/Theory  
reduced from 2.9  
to 1.7 (ALEPH data)

